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Numerical Simulation Research of Interior Ballistics Character for Non-lethal Strike Weapon System

Xiao-jun Zhai, Wei Luo*

Engineering College of CAPF, Xi'an, Shaanxi, 710086, China

Abstract

In order to adjust the transmitted energy and control the end effect, and adapt the needs of antiriot arm in the different use situation, which is a very difficult problem in non-lethal strike weapon domain. According to constant kinetic energy system theory, and in the base of choosing two-phase flow model of interior ballistics, and the Runge-Kutta scheme and MATLAB software are used to conduct numerical simulation to amelioration 18.4mm antiriot gun interior ballistics, and by comparing the numerical analysis result with experiment result, validate the model of interior ballistics and numerical simulation correctness, the laws about combustion and flow of powder were obtained, and the influence regularities of the variation of ventage place, gas vessel cubage and ventage radius on muzzle velocity of projectile are achieved, which provides theoretical foundation for further researches on the c non-lethal strike weapon system.

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Keywords: interior ballistics; two-phase flow; numerical simulation; constant kinetic energy strike.

1. Introduction

In recent years, domestic and foreign terrorist and violence events are taking place, and the particularity of the anti-terror work and struggle against terrorism has the special requirements to riot weapon equipment. Terrorist event damage degree and destroy is more and more strong, which requires the weapon can

* Corresponding author. Tel: +86-13991817117
E-mail address: 444570300@qq.com.

accurately and rapidly attack and inhibit implementation, and achieve the purpose of instantly and effective overmaster criminal, but the riot task of the large assembly, procession and large-scale riots activities, the environment of which is complex, the aim arisen time and distance constantly change, so the quickly change the field of fire, kill power adjustable and effect controllable non-lethal blow weapons are needed, so that complete the task of controlling the situation effective, dispersing the mob crowd and maintaining social order. Therefore, constant kinetic energy non-lethal weapons system in our country is not only need of the development of weapons and equipment, but also is to the research and development our country's existing non-lethal weapons a great boost.

The research of constant kinetic energy non-lethal weapons system in field of launch dynamics theory is innovative research. Foreign similar weapons and equipment usually adopt pneumatic launching, and by adjusting the pneumatic launch energy to control the end of the projectile performance, but the study of domestic is limited to a small amount. The interior ballistic mechanism of the kind of weapon system have significantly different with traditional weapons interior ballistic mechanism, what is difficult: one is that through what kind of method to release energy, and second is that what is relationship between energy of release and projectile velocity. Therefore, through the simulation method for the weapon system interior ballistic mechanism, make clear further study of the projectile velocity and discouraged relationship, for realizing this weapon system expected tactical and technical indexes are decisive role.

2. Interior ballistic model

2.1. Physical model^[2]

In order to simplify the questions, and make the model close to the real physical process fully, we make the following hypothesis^[3]:

- (1) A dimension flow hypothesis. Assumption is that the air of the chamber is a dimension flow in the most of the time and in the pipeline section.
- (2) Ignore the viscous dissipation of gas and the heat loss of chamber wall
- (3) Equal flow hypothesis. Hypothesis is that gunpowder particles and gas has the same movement speed.
- (4) single gunpowder particles are subject to the laws and burning geometry, gunpowder particles index burning law of the size and the shape of the agreement is strictly.
- (5) the gas phase state changes obey the Nobel Abel equation.

2.2. Mathematical model

One dimension and two phase flow interior ballistic model in part of chamber use the formula (1) ~ (8) of literature [4] section 6.4.

3. Numerical solution method

3.1. boundary conditions and initial conditions

Boundary conditions and initial conditions use literature [5] section 3.5 (3-79) ~ (3-84).

$$\frac{\partial U}{\partial t} + \frac{\partial F}{\partial x} = H \quad (1)$$

The basic equations use MacCormack difference scheme of two rank precision, the format uses alternately difference before and after format predict and calibrate calculation separately, format for:

Estimate calculation is

$$\bar{U}_j^{n+1} = U_j^n - \frac{\Delta t}{\Delta x} (F_{j+1}^n - F_j^n) + \Delta t H_j^n \quad (2)$$

Emendation calculation is

$$\tilde{U}_j^{n+1} = \bar{U}_j^{n+1} - \frac{\Delta t}{\Delta x} (\bar{F}_j^{n+1} - \bar{F}_{j-1}^{n+1}) + \Delta t \bar{H}_j^{n+1} \quad (3)$$

$$U_j^{n+1} = \frac{1}{2} (U_j^n + \tilde{U}_j^{n+1}) \quad (4)$$

CFL stability condition is:

$$\Delta t \leq \frac{C_0 \Delta x}{|u| + c} \quad (5)$$

4. Computer imitate result analysis

The paper takes in the left and right two sides tube of the 18.4 mm riot gun open hole and increase the gas chamber, and launch the kinetic energy ball of the charging conditions for an example to start simulation calculation and analysis.

4.1. The change of the pressure in the chambers simulation curve and analysis^[4, 5]

Choosing the opening hole center distance from the projectile top is 3mm, the of the hole is 2.4 mm, and indoor diameter is 2cm, pressure time curve is shown in figure1, and chamber pressure journey curve is shown in figure 2.

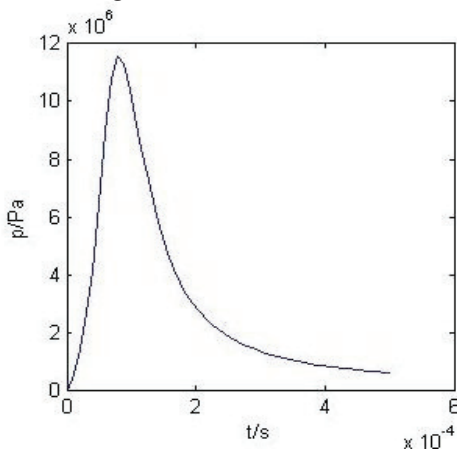


Figure1 chamber pressure time curve

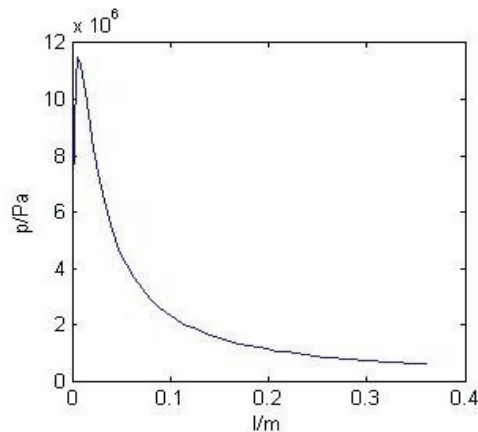


Figure2 chamber pressure journey curve

Figure 1 can see, the pressure in the chamber began to rise fast, achieve maximum quickly, and then with projectile movement rapidly decline, and gradually reduce to a gun muzzle pressure. Before 0.2ms,

gunpowder gas is burning quickly, lead to the pressure in the chamber rapid rise in a very short period of time, and with the movement of the projectile, the projectile bottom passes staleness hole, gunpowder gas outflows in part, with the space increasing, the gas pressure in the chamber drops rapidly, after 0.4ms, the pressure in the chamber drops to gently, which shows that the direction of the flow after a short change starts gradually stability.

The figure2 can see, after the projectile begins to move 0.02m, the pressure of the gun chamber rises up quickly to maximum, that is when the projectile has just started, the pressure achieves maximum soon, and then with the projectile moving forward, through discouraged hole, part of the gas flows, after increasing the space, the pressure in the chamber continues to drop. The pressure of the gun chamber in the declining process, the pressure curve gets gently, obviously which is caused by the indoor gas backflow.

4.2. Numerical simulation analysis of change of gas chamber volume affects interior ballistic behavior

The curve about the change of gas indoor diameter (the change of volume) having influence on the pressure in the chamber and the projectile speed, is shown in figure 3 and 4.

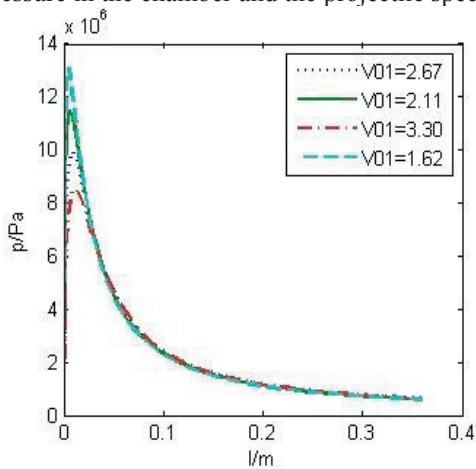


Figure3 change of gas indoor diameter influence on the pressure in the chamber

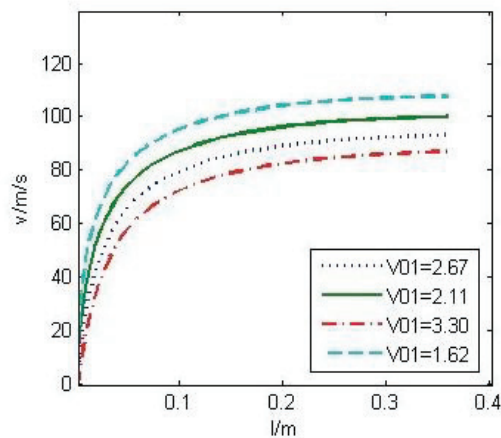


Figure4 change of gas indoor diameter influence on projectile muzzle velocity

From the above two figure can see, different air chamber volume, the change of pressure in the chamber is different, thus the projectile velocity is also different. We can see from the figure 3, along with the gas chamber volume increases, the maximum pressure in the chamber will decrease, the pressure in the chamber curve more concentrated, which explains that the four volume under the condition of the pressure change trend is the same. When gas volume increases to 3.3cm^3 , its peak will get minimum, but the curve of the pressure change compared to other quite gentle, and the pressure in the chamber drop smoothly. We can be seen from the figure 4, with the increase of the gas chamber volume, projectile velocity will step down, which is due to that the fall of the pressure in the chamber brings on the thrust down, and the projectile get the kinetic energy reduce.

4.3. The simulation analysis of change of staleness hole diameter influence on the performance of interior ballistic

In the other parameters remain unchanged, change staleness hole diameter, which in turn is 2.2 mm, 2.4 mm, 2.6 mm and 2.8 mm. Simulation results of staleness hole diameter variation of interior ballistic behavior are shown in figure 5 and 6.

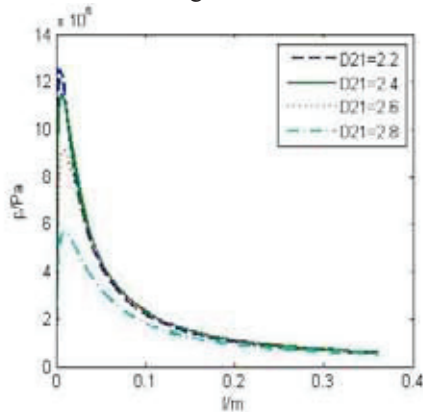


Figure 5 change of staleness hole diameter influence diameter

on the pressure in the chamber

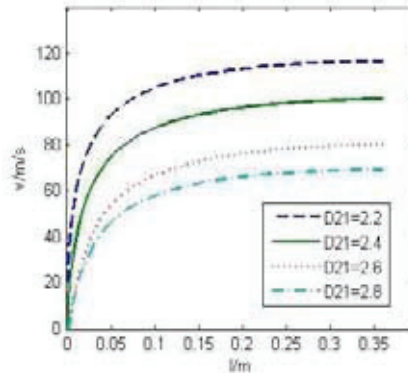


Figure 6 high pressure chamber orifices

on the influence of the projectile velocity

By the above two figures we can see, staleness hole diameter variation influences on interior ballistic behavior, along with the increase of the diameter, the peak of the pressure curve in the chamber will decline, and pressure curve tends gradually smooth. Also, speed is always reducing with the increase of the diameter. This is due to that with the increase of the diameter, the velocity and energy of gunpowder gas into the gas chamber are also increasing, as we can see when orifices $D_{21}=2.8$ mm in diameter, the first peak will appear, but with the movement of projectile, the increase of the space in the gas chamber and the outflow of the gunpowder gas, the pressure from the added value of the space increases lead to less than after the pressure drop value, so aperture, increase the pressure in the chamber, but lower peak speed also will be reduced.

5. The experimental data and the simulation results contrast

In order to validate the accuracy of the simulation model, the results of calculation was analyzed with specific experimental data.

Through measuring the chamber pressure in the process of riot gun launching, we can get pressure change curves. Because of the riot gun in the process of launching, the gunpowder gas produces a great impact, the pressure change curve more jagged type interference, so we can take chamber pressure maximum. But through the determination of chamber pressure maximum, we can get the change of all kinds of factors to the influence law of the biggest chamber pressure. The experimental results and numerical simulation results will be compared, and find the differences.

(1) Changes of staleness hole diameter bring influence on the biggest chamber pressure

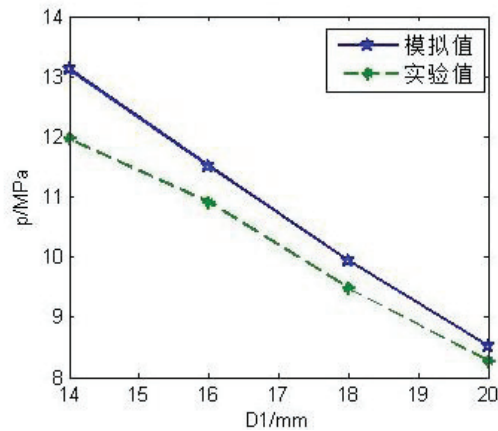


Figure7 Changes of staleness hole diameter bring influence on the biggest chamber pressure

What we can see from above, the experiment and simulation curve are basically parallel, which explains that numerical simulation model is accurate. Through the comparison, we can get that when average staleness hole diameter change of 2 mm, the maximum of pressure reduce 1.26 MPa. From this we get the relationship of between chamber pressure maximum and staleness hole diameter is:

$$p_{2m} = -0.6265 D_1 + 20.81$$

(2) Figure 8 changes of the gas indoor diameter bring influence on the projectile velocity

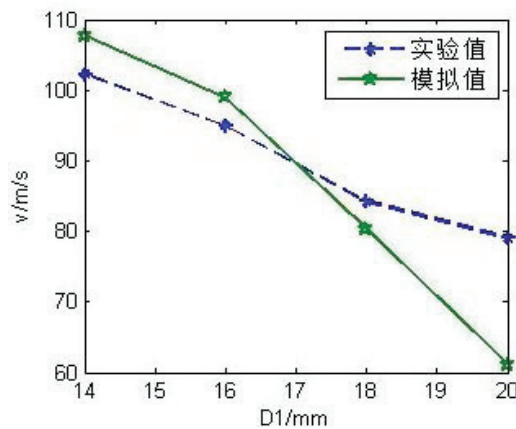


Figure 8 changes of the gas indoor diameter bring influence on the projectile velocity

Through the experiment and simulation value contrasting, we may find that the muzzle velocity declines with the increase of indoor size, but two curve downward trend are slightly different, and the experimental value curve more gentle decline. We can see, average gas indoor diameter increases 2 mm, projectile velocity to reduce 7 m/s or so. From this we find rules, the experimental value of projectile velocity with the change of gas chamber volume are: $v_0 = -4.015 D_1 + 158.4$

6. Conclusion

Through imitating and calculating improved 18.4 mm riot gun interior ballistic behavior, analysing and comparing the simulation results with experimental data, we can reach the following conclusion:

(1) Control the size of the aperture of the barrel or the volume of the gas chamber, by which we can realize the projectile velocity adjustment, which shows that the staleness and drop-press theory to realize the non-fatal constant kinetic energy strike is a feasible technology way.

(2) The interior ballistic model established and the simulation method used in the paper are completely suitable for the weapon system of using the staleness and drop-press theory to realize the non-fatal constant kinetic energy strike.

References

- [1] Jin ZhiMing, Weng ChunSheng. Higher interior ballistics within [M]. Beijing: higher education press, 2003.
- [2] Zhou YanHuang, Wang Shengcheng. Practical two phase flow interior ballistics [M]. Beijing: the weapon industry press, 1990, 3.
- [3] Weng ChunSheng, Wang hao. Calculation interior ballistics [M]. Beijing: national defense industry press, 2006.
- [4] Mary. mathematical experiment and modeling. MATLAB [M]. Beijing: Qinghua university press, 2010.1
- [5] Zhou WenBin, Zhou Yi etc. Application Simulink model design and optimization control system [J]. Computer simulation, 2007,8,98 ~ 101.